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Description

[IONIZED PHYSICAL VAPOR DEPOSITION PROCESS AND APPARATUS THEREOF]

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the priority benefit of Taiwan application serial no.92118826, filed on July 10, 2003.

BACKGROUND OF INVENTION

[0002] Field of the Invention

[0003] The present invention relates to a semiconductor fabrication process and associated apparatus. More particularly, the present invention relates to an ionized physical vapor deposition (I-PVD) process and apparatus thereof.

[0004] Description of the Related Art

[0005] In the process of fabricating semiconductor devices, metallic films are formed by performing a physical vapor deposition (PVD) process or a chemical vapor deposition (CVD) process. In general, the PVD process is more frequently used. However, the step coverage of a PVD pro-

cess is normally inferior to a CVD process.

[0006] To improve the step coverage of a PVD process, an ionized physical vapor deposition (I-PVD) process has been introduced. Through an ionization unit having a magnetic induction coil or a magnetic pole design, a portion of the neutral metallic atoms is ionized. The ionized metallic atoms are accelerated by an electric field (the electric field between a target and a wafer) towards the wafer. Hence, the ionized metallic atoms will shoot into the wafer surface perpendicularly and increase the step coverage of a deposited film.

[0007] In the aforementioned technique, a negative bias voltage is applied to the target and another smaller radio frequency (RF) negative bias voltage is applied to wafer. Hence, the positive metallic ions will be attracted by and accelerate towards the negatively bias wafer. Yet, the bombardment of accelerated ions on the surface of a wafer often results in some damages especially around the contact areas, which may lead to an increase in contact resistance.

SUMMARY OF INVENTION

[0008] Accordingly, one object of the present invention is to provide an ionized physical vapor deposition (I-PVD) process

and apparatus thereof that can improve step coverage and reduce damage to the surface of a wafer.

[0009] To achieve these and other advantages and in accordance with the purpose of the invention, as embodied and broadly described herein, the invention provides an ionized physical vapor deposition (I-PVD) apparatus. The I-PVD apparatus comprises a reaction chamber, a wafer pedestal, an ionization unit, a target and a conductive mesh. The wafer pedestal is set up on the bottom section of the reaction chamber for supporting a wafer. The target is set up over the wafer pedestal on the top cover of the reaction chamber. The top cover of the reaction chamber serves as an electrode. Obviously, another electrode plate inside the reaction chamber may be used as an electrode instead of the top cover electrode . The ionization unit is set up between the target and the wafer pedestal for ionizing the metallic atoms let loose from the target due to bombardment. The conductive mesh is set up between the ionization unit and the wafer pedestal serving as another electrode. The conductive mesh is positioned such that the distance from the wafer pedestal is much smaller than the distance to the target. The conductive mesh is separated from the wafer pedestal by a distance between 1 to

2 cm, for example.

[0010] This invention also provides an ionized physical vapor deposition (I-PVD) process. First, a plasma reaction chamber is provided. The plasma reaction chamber comprises a metal target and a wafer pedestal. An ionization unit is set up between the metal target and the wafer pedestal and a conductive mesh is set up between the ionization unit and the wafer pedestal. Thereafter, a wafer is put on the wafer pedestal and then the ionization unit is switched on. A negative bias voltage is applied to the metal target and another smaller negative bias voltage is applied to the conductive mesh so that a film is gradually deposited on the wafer.

[0011] In this invention, a conductive mesh is set up close to the wafer and a negative bias voltage is applied to the conductive mesh during the deposition process. Hence, the ionized metallic atoms will accelerate towards the mesh and the ionized metallic atoms will shoot into the wafer surface more perpendicularly, thereby improving the step coverage of the deposited film. Moreover, the positively charged metallic ions will be attracted by the negatively bias conductive mesh after passing through the mesh. Thus, the conductive mesh is able to decelerate the ions

before hitting the wafer. Consequently, damages to the wafer resulting from a heavy bombardment of metallic ions are minimized.

[0012] It is to be understood that both the foregoing general description and the following detailed description are exemplary, and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF DRAWINGS

[0013] The accompanying drawings are included to provide a further understanding of the invention, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

[0014] Fig. 1 is a diagram showing the component layout of an ionized physical vapor deposition apparatus according to one preferred embodiment of this invention.

[0015] Fig. 2 is a top view of the conductive mesh in Fig. 1.

[0016] Fig. 3 is a schematic cross-sectional view showing a thin film with a good step coverage over a wafer formed according to one preferred embodiment of this invention.

[0017] Figs. 4A and 4B are schematic cross-sectional views

showing a thin film with a good step coverage over a wafer formed according to another preferred embodiment of this invention.

DETAILED DESCRIPTION

[0018] Reference will now be made in detail to the present preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the description to refer to the same or like parts.

[0019] Fig. 1 is a diagram showing the component layout of an ionized physical vapor deposition apparatus according to one preferred embodiment of this invention. The ionized physical vapor deposition (I-PVD) apparatus comprises a reaction chamber 100, a wafer pedestal 104, a target 106, an ionization unit 106 and a conductive mesh 110.

[0020] The wafer pedestal 104 is set up on the bottom section of the reaction chamber 100 for supporting a wafer 112. The target 106 is fixed to a top section inside the reaction chamber 100. In one embodiment of this invention, the top cover 102 of the reaction chamber 100 is a conductive plate that may serve as an electrode. Furthermore, the top cover 102 is connected to a power supply 120 including,

for example, a direct current (DC) power supply. Hence, the target 106 is fastened to the surface of the top cover 102 over the wafer pedestal 104. In another embodiment of this invention, an additional electrode plate 102 is set up at the top section inside the reaction chamber 100 such that the electrode plate 102 is electrically connected to the DC power supply 120. The target 106 is attached to the surface of the electrode plate 102 over the wafer pedestal 104. The target 106 is fabricated from a metallic material including, for example, titanium, cobalt, nickel, tantalum, tungsten, aluminum or copper.

[0021] The ionization unit 108 is set up inside the reaction chamber 100 between the target 106 and the wafer pedestal 104 for ionizing metallic atoms let loose through bombardment. The ionization unit 108 can be a magnetic induction coil or magnetic pole piece, for example. Thus, the ionized physical vapor deposition (I-PVD) apparatus can be an ionized metal plasma (IMP) physical vapor deposition apparatus, a self-ionized plasma (SIP) physical vapor deposition apparatus, a hollow cathode magnetron sputtering (HCM) apparatus according to the type of ionization unit used. If a hollow cathode magnetron sputtering apparatus is used, the electrode plate 102 in Fig. 1

will integrate with a magnetic pole design to form a hollow structure.

[0022] The conductive mesh 110 is set up between the wafer pedestal 104 and the ionization unit 108. The conductive mesh 110 is positioned at a smaller distance away from the wafer pedestal 104 than the target 106. The conductive mesh 110 is separated from the wafer pedestal 104 by a distance between 1 to 2 cm, for example. In addition, the conductive mesh 110 is preferably fabricated using a material identical to the target 106 to prevent unwanted contamination during the deposition process.

[0023] The conductive mesh 110 has a metal net structure having a top view as shown in Fig. 2. Since the conductive mesh 110 is fabricated using a metallic material, the mesh 110 is electrically conductive and can serve as an electrode. Furthermore, the conductive mesh 110 is connected to a power supply 118 such as a radio frequency (RF) power supplier.

[0024] In addition, the ionized physical vapor deposition (I-PVD) apparatus further comprises a gas supply device 116 for delivering an inert gas such as argon while the physical vapor deposition process for forming a metallic film is carried out. Furthermore, reactive gases may pass into the

reaction chamber 100 selectively through a special channel so that the reactive gases can participate in the vapor deposition to form a thin film the metallic compound. For example, if the target 106 is fabricated using titanium, the gas supply device 116 may deliver argon and nitrogen into the reaction chamber 100 for producing a titanium nitride thin film on the surface of the wafer 112.

[0025] An ionized physical vapor deposition (I-PVD) process for forming a thin film over a wafer can be carried using the I-PVD apparatus as shown in Fig. 1. First, a wafer 112 is put on the wafer pedestal 104 inside the reaction chamber 100 ready for receiving a layer of deposited thin film. A cross-sectional view of the wafer 112 is shown in Fig. 3. The wafer 112 comprises a silicon substrate 200 and a dielectric layer 202 over the substrate 200. The dielectric layer 202 has an opening 204. Thereafter, the power suppliers 118 and 120 is initialized such that a negative bias voltage is applied to the target 106 and another smaller negative bias voltage is applied to the conductive mesh 110. The plasma thus produced bombarded the target 106 to produces free metallic atoms 113. In the meantime, the ionization unit 108 is switched on so that the loose metallic atoms 113 are ionized into positively

charged metallic ions 114.

[0026] The electric field between the ionized metallic atoms 114 and the conductive mesh 110 accelerates the ionized metallic atoms 114 to shoot at the conductive mesh 110. With the acceleration, the ionized metallic atoms 114 will bombard the wafer 112 perpendicularly and improve the step coverage of the deposited thin film. However, as the ionized metallic atoms 114 pass through the conductive mesh 110, the positively charged metallic atoms 114 will be subjected to the backward attraction of the negatively biased conductive mesh 110. Hence, the ionized metallic atoms 114 will decelerate a little before reaching the wafer 112. In other words, the average energy of the metallic atoms 114 bombarding the wafer 112 is greatly reduced. As shown in Fig. 3, the thin film 206 on the surface dielectric layer 202 and a portion of the substrate 200 has good step coverage. Furthermore, damages to the surface of the dielectric layer 202 and the substrate 200 resulting from bombarding the wafer 112 with accelerated ionized metallic atoms 114 are minimized.

[0027] An example that illustrates the deployment of an I-PVD apparatus to carry out an I-PVD process includes depositing titanium using an ionized metal plasma (IMP) PVC ap-

paratus. In this particular case, the negative bias voltage that applies to the target is a direct current (DC) source with power set to a level between 1000 to 3000 Watts and the negative bias voltage that applies to the conductive mesh is a radio frequency source with power set to a level between 50 to 200 Watts.

[0028] In another embodiment of this invention, a film layer is deposited over the dielectric layer 202 and the substrate 200 before the thin film 206.Figs. 4A and 4B are schematic cross-sectional views showing a thin film with a good step coverage over a wafer formed according to another preferred embodiment of this invention. As shown in Figs. 1 and 4A, a wafer 112 is put on the wafer pedestal 104 inside the reaction chamber 100. Thereafter, the power supply 120 is turned on to apply a negative bias voltage to the target 106 but no bias voltage is applied to the conductive mesh 110 yet. In the meantime, the ionization unit 108 is turned on to ionize the metallic atoms 113 bombarded out of the target 106 into positively charged metallic ions 114. Since the conductive mesh 110 is not voltage biased, the metallic ions 114 pass through the conductive mesh 110 with and travel towards the wafer 112 with moderate acceleration. Ultimately, a film

layer 210 is formed over the dielectric layer 202 and the substrate 200. The film layer 210 has an overall thickness roughly 20% to 30% (40Å to 50Å, for example) of the final thickness of the thin film 206. Because the deposition process is carried out without applying any bias voltage to the conductive mesh 110, the film layer 210 has poor step coverage. Yet, the ultimate step coverage of the thin film is relatively unaffected because overall thickness of the thin film 210 is small.

[0029] As shown in Figs. 1 and 4B, a negative bias voltage is again applied to the target 106 and another smaller negative bias voltage is applied to the conductive mesh 110. Similarly, the ionization unit 108 is turned on to ionize the metallic atoms 113 bombarded out of the target 106 into positively charged metallic ions 114. The electric field between the target 106 and the conductive mesh 110 accelerates the ionized metallic atoms 114 towards the wafer 112. Hence, the ionized metallic atoms 114 will shoot perpendicularly into the wafer 112 and improve the step coverage of the thin film. However, the positively charged ions 114 will be attracted by the negatively bias conductive mesh 110 after passing through the mesh 110. Thus, the conductive mesh 100 is able to decelerate the ions

114 on its way to the wafer 112. The thin film 206 over the film layer 210 has a thickness of about 200Å or more and has good step coverage. With the film layer 210 covering both the dielectric layer 202 and the substrate 200, the amount of damages to the wafer 112 resulting from the bombardment of metallic ions 114 is greatly reduced.

[0030] In the aforementioned embodiment, if the thin film to be deposited on the wafer is a metallic compound, an additional reaction gas is also passed into the reaction chamber 100 all through the reaction process.

[0031] In this invention, a conductive mesh is set up close to the wafer and a negative bias voltage is applied to the conductive mesh. Hence, ionized metallic atoms will accelerate towards the mesh and improve the step coverage of a deposited film. The negative voltage biased mesh also decelerates the ionized metallic atoms before reaching the wafer so that damage to the wafer resulting from the bombardment by the metallic ions is greatly reduced.

[0032] In addition, a film layer may be deposited over the wafer without applying a negative bias voltage to the conductive mesh prior to forming the thin film. The film layer protects the wafer against direct bombardment by ionized metallic atoms during a subsequent thin film deposition

process.

[0033] It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present invention without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the present invention cover modifications and variations of this invention provided they fall within the scope of the following claims and their equivalents.